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SPECIFICATION

IMPROVEMENTS TO COLOR FLAT PANEL DISPLAY SUB-PIXEL ARRANGEMENTS AND LAYOUTS

CROSS-REFERENCE TO RELATED APPLICATION

The present application claims the benefit of the date of the U.S. Provisional Patent Application Serial No. 60/290,103, entitled "Improvements to Color Flat Panel Display Sub-Pixel Arrangements and Layouts", filed on May 9, 2001, which is incorporated herein in its entirety.

BACKGROUND

The present application relates to improvements to display layouts, and specifically to improved color pixel arrangements and means of addressing used in displays.

The present state of the art of color single plane imaging matrix, for flat panel displays use the red-green-blue (RGB) color triad or a single color in a vertical stripe as shown in prior art FIG 1. Prior art FIG. 1 shows an arrangement 10 having several three-color pixel elements with red emitters (or sub-pixels) 14, blue emitters 16, and green emitters 12. The arrangement takes advantage of the Von Bezold effect by separating the three colors and placing equal spatial frequency weight on each color. However, this panel suffers because of inadequate attention to how human vision operates. These types of panels are a poor match to human vision.

Full color perception is produced in the eye by three-color receptor nerve cell types called cones. The three types are sensitive to different wavelengths of light: long, medium, and short ("red", "green", and "blue", respectively). The relative density of the three differs significantly from one another. There are slightly more red receptors than green receptors. There are very few blue receptors compared to red or green receptors.

The human vision system processes the information detected by the eye in several perceptual channels: luminance, chromanance, and motion. Motion is only important for flicker threshold to the imaging system designer. The luminance channel takes the input from only the red and green receptors. It is "color blind". It processes the information in

such a manner that the contrast of edges is enhanced. The chromanance channel does not have edge contrast enhancement. Since the luminance channel uses and enhances every red and green receptor, the resolution of the luminance channel is several times higher than the chromanance channels. The blue receptor contribution to luminance perception is negligible. The luminance channel acts as a resolution band pass filter. Its peak response is at 35 cycles per degree (cycles/°). It limits the response at 0 cycles/° and at 50 cycles/° in the horizontal and vertical axis. This means that the luminance channel can only tell the relative brightness between two areas within the field of view. It cannot tell the absolute brightness. Further, if any detail is finer than 50 cycles/°, it simply blends together. The limit in the diagonal axes is significantly lower.

The chromanance channel is further subdivided into two sub-channels, to allow us to see full color. These channels are quite different from the luminance channel, acting as low pass filters. One can always tell what color an object is, no matter how big it is in our field of view. The red/green chromanance sub-channel resolution limit is at 8 cycles/°, while the yellow/blue chromanance sub-channel resolution limit is at 4 cycles/°. Thus, the error introduced by lowering the blue resolution by one octave will be barely noticeable by the most perceptive viewer, if at all, as experiments at Xerox and NASA,

Ames Research Center (R. Martin, J. Gille, J. Larimer, Detectability of Reduced Blue Pixel Count in Projection Displays, SID Digest 1993) have demonstrated.

The luminance channel determines image details by analyzing the spatial frequency Fourier transform components. From signal theory, any given signal can be represented as the summation of a series of sine waves of varying amplitude and frequency. The process of teasing out, mathematically, these sine-wave-components of a given signal is called a Fourier Transform. The human vision system responds to these sine-wave-components in the two-dimensional image signal.

Color perception is influenced by a process called "assimilation" or the Von Bezold color blending effect. This is what allows separate color pixels (also known as sub-pixels or emitters) of a display to be perceived as a mixed color. This blending effect happens over a given angular distance in the field of view. Because of the relatively scarce blue receptors, this blending happens over a greater angle for blue than for red or green. This distance is approximately 0.25° for blue, while for red or green it is approximately 0.12°. At a viewing distance of twelve inches, 0.25° subtends 50 mils (1,270 µ) on a display. Thus, if the blue pixel pitch is less than half (625 µ) of this blending pitch, the colors will blend without loss of picture quality. This blending effect

is directly related to the chromanance sub-channel resolution limits described above. Below the resolution limit, one sees separate colors, above the resolution limit, one sees the combined color.

Examining the conventional RGB stripe display in prior art FIG. 1, the design assumes that all three colors have the same resolution. The design also assumes that the luminance information and the chromanance information have the same spatial resolution. Further, keeping in mind that the blue sub-pixel is not perceived by the human luminance channel and is therefore seen as a black dot, and since the blue sub-pixel is aligned in stripes, the human viewer sees vertical black lines on the screen as shown in FIG. 2. The image displayed has large areas of white space, such as when displaying black text on a white background. These stripes are viewed as a distracting screen artifact. Typical higher resolution prior art displays have pixel densities of 90 pixels per inch. At an average viewing distance of 18 inches, this represents approximately 28 pixels per degree or approximately 14 cycles/°, when showing lines and spaces at the highest Modulation Transfer Function (MTF) allowed by the display. However, what the luminance channel sees is an approximately 28 cycles/° signal horizontally across a white image when considering that the blue sub-pixel 12 is dark

compared to the red 14 and green 16 emitters, as shown in prior art FIG 2. This 28 cycles/° artifact is closer to the peak luminance channel response spatial frequency, 35 cycles/°, than the desired image signal, 14 cycles/°, thus competing for the viewer's attention.

Thus, the prior art arrangement of three-color emitters is shown to be a poor match to human vision.

SUMMARY

A system of addressing an array of color pixels for a flat panel display is disclosed. More particularly, the layout of column and row drive lines and transistors of three-color pixel element of spaced-apart emitters is disclosed.

The three-color pixel element has square design disposed at the origin of an X, Y coordinate system. Disposed at the center of the square is a blue emitter. Red emitters are disposed in the second and fourth quadrants not occupied by the blue emitter and green emitters are disposed in the first and third quadrants not occupied by the blue emitter. The blue emitter is square shaped, having corners aligned at the X and Y axes of the coordinate system, and the opposing pairs of red and green emitters are generally

square shaped, having truncated inwardly-facing corners forming edges parallel to the sides of the blue emitter. The plurality of three-color pixel elements may be arranged in rows and columns to form a display. This array provides better perceived resolution and appearance of single full color displays by matching the human vision system.

Each emitter has a transistor and associated components or structures, such as capacitors. The column lines and row lines are doubled to allow for the transistors and associated structures of the red emitters and green emitters to be gathered together at the interstitial corners between the three-color pixel elements creating combined transistor groups. With the transistors grouped together, the combined transistors groups and the blue emitters both become less visible at 56 cycles/°, virtually vanishing from sight almost entirely.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the figures, wherein like elements are numbered alike:

FIG. 1 illustrates a prior art RGB stripe arrangement of three-color pixel elements in an array, a single plane, for a display device;

FIG. 2 illustrates a prior art RGB stripe arrangement as it would be perceived by the luminance channel of the human vision system when a full white image is displayed;

FIG. 3 illustrates an arrangement of three-color pixel elements in an array, in a single plane, for a display device;

FIG. 4 illustrates the arrangement of FIG 3, as the luminance channel of the human vision system would perceive it when a full white image is displayed;

FIG. 5 illustrates a layout of drive lines and transistors for the arrangement of pixel elements of FIG. 4; and

FIG. 6 illustrates the arrangement of FIG 5, as it would be perceived by the luminance channel of the human vision system, prior to filtering, when a full white image is displayed.

DETAILED DESCRIPTION

Those of ordinary skill in the art will realize that the following is illustrative only and not in any way limiting. Other embodiments will readily suggest themselves to such skilled persons.

FIG. 3 illustrates an arrangement 20 of several three-color pixel elements according to a preferred embodiment. A three-color pixel element 21 consists of a blue emitter (or sub-pixel) 22, two red emitters 24, and two green emitters 26 in a square, which is described as follows. The three-color pixel element 21 is square shaped and is centered at the origin of an X, Y coordinate system. The blue emitter 22 is centered at the origin of the square and extends into the first, second, third, and fourth quadrants of the X, Y coordinate system. A pair of red emitters 24 are disposed in opposing quadrants (i.e., the second and the fourth quadrants), and a pair of green emitters 26 are disposed in opposing quadrants (i.e., the first and the third quadrants), occupying the portions of the quadrants not occupied by the blue emitter 22. As shown in FIG. 3, the blue emitter 22 can be square-shaped, having corners aligned at the X and Y axes of the coordinate system, and the opposing pairs of red 24 and green 26 emitters can be generally square shaped, having truncated inwardly-facing corners forming edges parallel to the sides of the blue emitter 22.

The array is repeated across a panel to complete a device with a desired matrix resolution. The repeating three-color pixels form a "checker board" of alternating red 24 and green 26 emitters with blue emitters 22 distributed evenly across the device.

However, the blue emitters 22 are at half the resolution of the red 24 and green 26 emitters.

One advantage of the three-color pixel element array is improved resolution of color displays. This occurs since only the red and green emitters contribute significantly to the perception of high resolution in the luminance channel. Thus, reducing the number of blue emitters and replacing some with red and green emitters improves resolution by more closely matching human vision.

Dividing the red and green emitters in half in the vertical axis to increase spatial addressability is an improvement over the conventional vertical single color stripe of the prior art. An alternating "checkerboard" of red and green emitters allows the Modulation Transfer Function (MTF), high spatial frequency resolution, to increase in both the horizontal and the vertical axes. A further advantage of this arrangement over prior art is the shape and location of the blue emitter.

In the prior art arrangement of FIG. 1, the blue emitters are in stripes. When viewed, the luminance channel of the human vision system sees these blue emitters as black stripes alternating with white stripes, as illustrated in prior art FIG. 2. In the horizontal direction, there are faint, but discernable lines between rows of three-color

pixel elements, largely due to the presence of the transistors, and/or associated structures, such as capacitors, at each emitter, as is common in the art. However, with the arrangement of FIG. 3, when viewed, the luminance channel of the human vision system sees black dots alternating with white dots as illustrated in FIG 4. This is an improvement because the spatial frequency, Fourier Transform wave component, energy is now spread into every axis, vertical, diagonal, as well as horizontal, reducing the amplitude of the original horizontal signal, and thus, the visual response (i.e., visibility).

FIG. 5 illustrates a preferred embodiment wherein only four three-color pixel elements 32, 34, 36, and 38 are grouped in arrangement 30, while several thousand can be arranged in an array. Column address drive lines 40, 42, 44, 46, and 48 and row address drive line 50 drive each three color pixel element 32, 34, 36, and 38. Each emitter has a transistor, and possibly associated structures such as a capacitor, which may be a sample/hold transistor/capacitor circuit. Therefore, each blue emitter 22 has a transistor 52, each red emitter 24 has a transistor 54, and each green emitter 26 has a transistor 56. Having two column lines 44 and two row lines 50 allows for the transistors, and/or associated structures, for the red emitters and green emitters to be

gathered together into the interstitial corners between the three-color pixel elements 32, 34, 36, and 38 creating combined transistor groups 58.

The grouping of the transistors and/or associated structures, such as capacitors, in the interstitial corners appears to be counter to good design practice, as understood in the prior art, since collecting them together makes them a bigger, and thus more visible dark spot, as shown in FIG 6. However, in this circumstance these dark spots are exactly halfway between the blue emitter 22 in each three-color pixel element.

In this embodiment, the spatial frequency of the combined transistor groups and/or associated structures, 58 and the blue emitter 22 is doubled, pushing them above the 50 cycles/° resolution limit of the luminance channel of human vision. For example, in a 90 pixel per inch display panel the blue emitter pitch, without the grouped transistors, would create a 28 cycles/° luminance channel signal, both horizontally and vertically. In other words, the blue emitters may be visible as a texture on solid white areas of a display. However, they will not be as visible as the stripes visible in the prior art.

In contrast, with the transistors grouped together, the combined group transistors 58 and the blue emitters 22 both become less visible at 56 cycles/°, virtually vanishing from sight almost entirely. In other words, the grouping of the transistors and the blue

emitters combine to produce a texture on solid white areas of a display too fine for the human visual system to see. In using this embodiment, the solid white areas become as smooth looking as a sheet of paper.

The grouping of the transistors, and/or associated structures, and placement of the blue emitters work together to match to human vision. In contrast to the prior art, which creates black lines with the placement of the blue emitters and transistor, the arrangement of the present invention removes this problem. In placing the transistors in accordance with the above arrangements, the transistors and blue emitters vanish from sight almost entirely providing a smooth looking display without a visible texture.

While the invention has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but

that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is: